ULTRAVIOLET BANDS OF CO IN THE ELECTRODELESS RING DISCHARGE

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Abstract

The relative intensities of the band systems of CO in the region 2900 to 2150A obtained in an electrodeless ring discharge at various pressures were observed, and compared with Geissler tube spectra. A continuous wave oscillator using 100 watts at 6400 kilocycles was used to produce the ring discharge.

Cameron bands. This system was well developed in the ring at low pressures, in contrast with results obtained by Herzberg who failed to obtain it in the ring excited by damped oscillations. The 0–1 band at 2157A was observed in addition to previously known members of the system.

Bands of the CO^+ ion. In the ring at all pressures, the first negative bands (CO^+) were strong, indicating the presence of ions in the ring. The comet-tail bands, due to the same ion, appeared only at low pressures.

Fourth positive bands. This system is very strong in the Geissler tube, and in the ring at high pressures. At low pressures it is very weak in comparison with the Cameron bands.

The observations show that the electrodeless ring discharge affords a means of selective excitation of certain band systems, and should prove of value in the study of overlapping systems.

Introduction

The investigation of which this work is a part, has for its purpose a study of the effectiveness of the electrodeless ring discharge maintained by a continuous wave oscillator as a source of band spectra, in which various band systems may be emphasized or suppressed by controlling the conditions of the discharge.

Factors under control in this form of discharge include the frequency and power input of the oscillator, and the pressure of the gas. The results here presented were obtained by varying only the pressure of the gas, keeping the frequency and the power input fixed. Comparison is made with spectra obtained in the conventional π-shaped Geissler tube.

Carbon monoxide was used in this work because of the large number of known bands in accessible portions of the spectrum. The bands here considered in detail lie in the region 2150 to 2900A.

An exhaustive study of CO bands was made by Herzberg[1] in 1928; however he used the electrodeless ring discharge maintained by damped oscillations of a condenser discharging through a spark gap, and apparently obtained a less energetic discharge than that produced by our tube-driven oscillator.

[1] G. Herzberg, Zeits. f. Physik **52**, 815 (1928).

Description of Apparatus

Oscillator. A wiring diagram of the oscillator is given in Fig. 1. The tube was a UX-852 with a maximum safe plate dissipation of 100 watts. The plate supply was obtained by full wave rectification of the high tension output of two transformers connected in series, using a pair of kenotrons. The plate voltage was controlled by inserting resistance in series with the primaries of the transformers. The maximum plate potential which could be used was about 1250 volts; higher voltages caused sparking across the variable air condenser *C*. The plate current was about 80 milliamperes, and the oscillating current about 1 ampere.

The inductance of the oscillating circuit was a $5\frac{1}{2}$ turn helix 35 cm in diameter of 1 cm copper tubing, surrounding the sphere in which the discharge occurred. The capacity, as shown in the diagram, was the plate to grid capacity of the tube. The variable air condenser *C* acted as a blocking con-

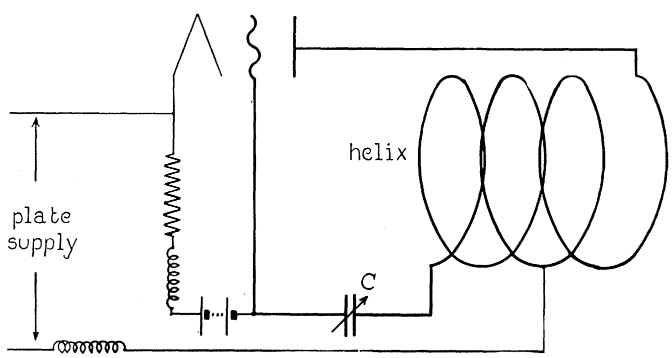


Fig. 1. Wiring diagram of 32 meter oscillator.

denser, and had only a small effect on the frequency, amounting to a 7 percent change in frequency for extreme settings of the condenser. The wavelength was 32 meters, corresponding to a frequency of 9400 kilocycles.

Discharge bulb. The electrodeless discharge was obtained in a 12 liter Pyrex flask with a diameter of 29 cm, provided with a tangential neck with a quartz window sealed on by means of a quartz to pyrex graded seal. The position of the helix surrounding the sphere could be adjusted so as to have the window well illuminated by the discharge.

Gas generator. The carbon monoxide was obtained by dropping formic acid into warm concentrated sulfuric acid. It was purified over KOH, dried over P_2O_5, and admitted into the discharge bulb through stop cocks. From the discharge bulb extended connections to a liquid air trap, a McLeod gauge, a mercury cut-off, a mercury diffusion pump, and a backing pump. For comparison purposes, a Π-shaped Geissler tube with a quartz window was attached to the system. It was excited by 60 cycle A. C. at 1100 volts through a 5000 ohm resistor.

Spectrograph. The spectrograph was a Féry prism type, giving a spectrum 11 cm long for the range 2150–2900A. In the absence of means for impressing a wave length scale or a comparison spectrum on the film, a wave-length scale was made to fit microphotometer records of an iron arc spectrum. With the aid of mercury lines and known bands, the scale could be fitted to microphotometer curves and to enlargements of the spectra studied. This method permitted errors of a few Angstrom units, but was considered sufficiently reliable for purposes of identification. Greater accuracy in wave-length measurements will require the construction of a source to be used with the grating spectrographs of the laboratory.

Experimental Procedure

As a result of a number of experiments in which discharge conditions were varied somewhat at random, it was found that the most interesting bands in the region studied were obtained at high energy input[2] at various pressures of the gas. Accordingly the series of exposures reproduced in Fig. 2 was made.

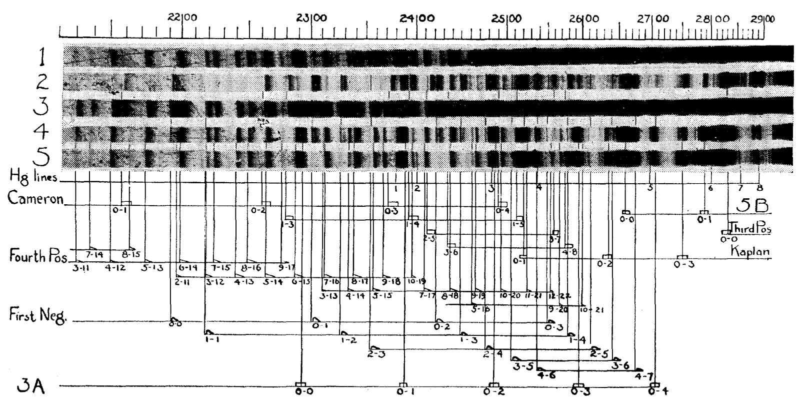


Fig. 2. Spectra of CO in the Geissler tube and the ring discharge.

Exposure No.	Source	Pressure (mm)	Time
1	Geissler tube discharge	0.15	6 min.
2	Electrodeless ring discharge	0.0002 to 0.0013	4.5 hr.
3	Electrodeless ring discharge	0.012 to 0.14	2.0 hr.
4	Electrodeless ring discharge	0.6 or more	0.5 hr.
5	Geissler tube discharge	0.42	8 min.

Marked lines due to mercury, wave-lengths from International Critical Tables Vol. 5.

1	2378.3	3	2482.7	5	2698.9	7	2847.7
2	2399.4	4	2536.	6	2803.6	8	2893.6

Exposures 1 and 5 were made with the Geissler tube for comparison; the pressure for exposure 1 (0.15 mm) being that for maximum brilliancy of the discharge with the voltage applied to the tube. The range through which the tube operated on 1100 volts was between about 0.06 and 0.42 mm pressure.

The electrodeless discharge, on the other hand, could be maintained at pressures as low as 0.0002 mm and up to several mm. Exposures 2, 3, and 4

[2] H. P. Knauss and J. C. Cotton, Phys. Rev. **36**, 1099 (1930).

are typical of low, intermediate, and high pressure discharges respectively. A scale of wave lengths and identifications of bands are included in Fig. 2. Exposure times have been selected to compensate somewhat for differences in the brightness of the sources.

Results and Discussion

Bands emphasized by ring discharge. The first negative group of carbon[3] appears strongly in the ring discharge at all pressures. This system is emitted by the CO^+ ion, and thus indicates the presence of these ions in the ring discharge. In the Geissler tube, on the contrary, the ions apparently are pulled into the electrodes by the electric field, and are present in smaller numbers. These bands were observed by Herzberg[1] in the electrodeless discharge maintained by damped oscillations.

Bands emphasized by low pressures. Attention has already been called[2] to the occurrence of the Cameron bands[4] in the ring discharge at low pressures. Herzberg[1] failed to obtain these in spite of long exposures at low pressures. It is probable that the excitation was not intense enough in his case to produce the Cameron bands, since exposures made with less power in our oscillator also failed to bring out these bands. This system was discovered[4] in neon with CO present in small quantities. Hopfield and Birge[5] obtained Cameron bands in absorption in pure CO. (They did not obtain them in emission, our statement[2] to the contrary being a misreading of the abstract[5] of their preliminary report.) Duffendack and Fox[6] tried unsuccessfully to obtain the Cameron bands in the low voltage arc.

Of the bands labelled in Fig. 2, all had previously been identified, with the exception of the $0-1$ Cameron band. This band is clearly present in exposures 2 and 3 (low and intermediate pressures, respectively) but absent in exposure 4 (high pressure) and in the Geissler spectra, exposures 1 and 5. The other bands of the system show a similar behavior in the original spectrum photograph, although this may not be obvious in the reproduction. The disappearance of these bands at high pressures indicates that the molecule leaves the initial state more readily by impact than by radiation, when the impacts are frequent.

The comet-tail system of CO (in the visible region, not included in Fig. 2) is strongly developed in the ring discharge at low pressures. This system was obtained also by Herzberg.[1]

The fourth positive bands are strong in the Geissler discharge and in exposure 4 (high pressure), but almost entirely absent in exposure 2 (low pressure). This illustrates again the dependence of relative intensities of bands on excitation conditions, so that disagreements of intensity estimates recorded[7,8] by various workers are not surprising.

[3] C. M. Blackburn, Proc. Natl. Acad. Sci. **11**, 28 (1927).
[4] H. B. Cameron, Phil. Mag. **1**, 405 (1926).
[5] J. J. Hopfield and R. T. Birge, Phys. Rev. **29**, 922 (1927).
[6] O. S. Duffendack and G. W. Fox, Astrophys. J. **65**, 214 (1927).
[7] R. T. Birge, Phys. Rev. **28**, 1157 (1926).
[8] R. S. Estey, Phys. Rev. **35**, 309 (1930).

The bands discovered by Kaplan[9] were originally observed in a Geissler tube containing hydrogen with a trace of CO. In our photographs they appear in both the ring and the Geissler discharges in pure CO. We also obtained them in the ring discharge in hydrogen at low pressure with a trace of CO. It is of interest to note that the Cameron bands also appeared under the latter conditions, although they were not present in the Geissler discharge observed by Kaplan.

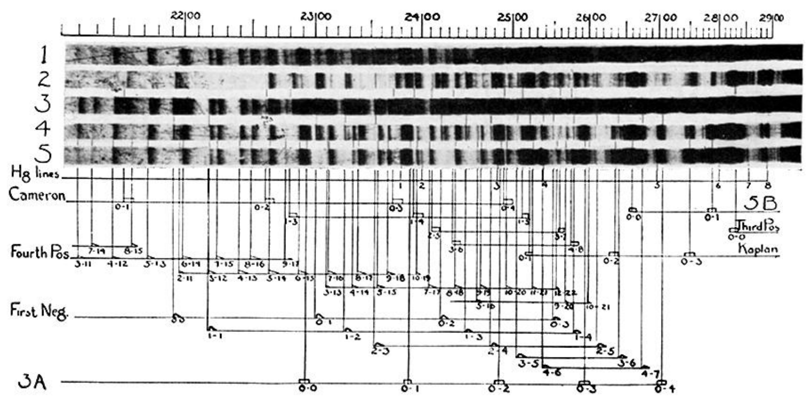
The 3A bands, like the fourth positive system, are very much weakened at lower pressures. The 5B system is affected in the same way, but not nearly as much.

Conclusions

Two principal conclusions about the electrodeless ring discharge as a source of bands may be pointed out. The first, which was established by earlier work, with damped oscillations causing the ring, is that spectra of molecular *ions* are enhanced in this source. The second, which was suspected before, but not fully realized experimentally, is that "low pressure bands" or bands which involve transitions with small probabilities can be brought out in the ring at low pressures, since this source permits reasonable intensities of discharge at pressures considerably lower than those at which Geissler tubes operate. The power available for excitation in the earlier work apparently was insufficient, a limitation which is readily overcome by means of the vacuum tube.

The writers are pleased to have had an opportunity to discuss their results with Professor R. T. Birge during his stay here.

[9] J. Kaplan, Phys. Rev. **35**, 1298 (1930).



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